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AUTHOR Carter, Richard D.; And Others
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ABSTRACT

The use of canonical analysis and multiple discriminant analysis to analyze equity-parity in colleges and universities is assessed and distinguished from multiple regression analysis. Multiple regression analysis forces the variable weights throughout the salary structure to be uniform, permits only one criterion or dependent variable to be examined at a time, restricts the coordinates to those provided by the variables as measured, and treats qualitative or discrete variables as if they were continuous, assuming ordinality of the numbers used. Canonical analysis and multiple discriminant analysis, both of which define new coordinate systems evaluation of dimensions underlying salary decisions, are multivariate alternatives to multiple regression analysis. These alternative techniques identify new coordinates in terms of the eigenvalues and eigenvectors of the appropriate correlation-covariance or dispersion matrices. Canonical analysis and multiple discriminant analysis were used in an annual salary adjustment process at the University of Wisconsin-Superior. Data for all full-time ranked faculty with a 100 percent appointment were analyzed for 2 successive years. Statistics for the 113 faculty members in the 1981-1982 study and the 111 faculty members in the 1982-1983 study are examined. (SW)

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MULTIVARIATE ALTERNATIVES TO REGRESSION ANALYSIS IN THE EVALUATION OF SALARY EQUITY-PARITY

Richard D. Carter

Director of Analysis and Planning

University of Wisconsin-Superior

Superior, WI 54880

(715) 394-8506

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Rhea S. Das

Professor and Program Coordinator, Psychology

University of Wisconsin-Superior

Superior, WI 54880

(715) 394-8312

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Andrea H. Garnello

Graduate Assistant, University of Wisconsin-Superior

Superior, WI 54880

(715) 394-8506

Richard C. Charboneau

Instructional Computing Assistant, University of Wisconsin-Superior

Superior, WI 54880

(715) 394-8312

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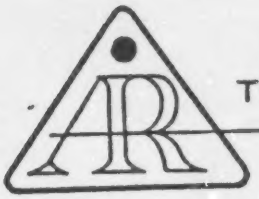

THE ASSOCIATION FOR INSTITUTIONAL RESEARCH

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D. R. Coleman, Chairman
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ABSTRACT

The analysis of salary equity-parity in institutions of higher education typically involves the use of multiple regression analysis to determine predicted salary and the residual differences between predicted and actual salary. Multiple regression analysis forces the variable weights throughout the salary structure to be uniform, permits only one criterion or dependent variable to be examined at a time, restricts the coordinates to those provided by the variables as measured, and as customarily used, treats qualitative or discrete variables as if they were continuous, assuming ordinality of the numbers used. Two multivariate alternatives to regresssion analysis are presented, canonical analysis and multiple discriminant analysis, both of which define new coordinate systems for evaluation of dimensions underlying salary decisions.

Multivariate Alternatives to Regression Analysis in the Evaluation of Salary Equity-Parity

While the term "equity" emphasizes fairness and impartiality in decisions, the term "parity" focuses upon equality. The former term appears to be more legal in the original meaning, while the latter term appears more in the context of financial affairs. Stemming from two different Latin roots, and arriving in contemporary English via different etymological routes, the two terms have come to be used, individually and together, to refer to the monetary compensation of work without regard to the gender or ethnicity of the individual performing that work. The interchangeability of the terms, and their usage as a compound term, are illustrated in literature published in the last five years (e.g., Beaumont, 1978; Brascamp and Johnson, 1978).

To determine whether or not individuals of comparable qualification performing comparable work are indeed paid comparably, multiple regression analysis of the salaries received by employees is carried out, with deviations from the actual or observed salary being compared with the predicted or expected salary as determined by the multiple regression equation fitted to the salary data. In the context of higher education, this often means that gender (e.g., Brascamp & Johnson, 1978; Buford & Norris, 1980-81; Danielson & Smith, 1981; Beaumont, 1978; Risher & Cameron, 1981-82), academic discipline (e.g., Beaumont, 1978; Tanur & Coser, 1978), tenure status or potential (e.g., Brascamp & Johnson, 1978; Tanur & Coser, 1978) are

introduced as predictor or independent variables in a multiple regression equation which may also include such other variables as level of education (e.g., Risher & Cameron, 1981-1982). Although the use of discrete or qualitative variables, lacking ordinality, is frequently inappropriate for the type of multiple regression analysis employed, it is usually justified in terms of the concept of "dummy" variables. There is a statistically elegant alternative to multiple regression analysis which allows evaluation of comparability of groups, i.e., individuals categorized according to discrete or qualitative variables, without violation of underlying assumptions. That alternative, multiple discriminant analysis, not only indicates whether or not the groups (e.g., faculty classified according to gender, academic discipline, or tenure status) differ significantly in terms of a set of multiple variables (e.g., salary, academic rank, student credit hour production), but also statistically identifies those individuals who have been misclassified. Equity-parity is demonstrated when the discriminant analysis is not statistically significant.

In addition to the problem of handling discrete or qualitative variables, multiple regression analysis can be carried out for only one criterion or dependent variable at a time. This is frequently salary, although other measures of compensation could also be considered. The most salient of these is probably academic rank. Since equity-parity in its contemporary sense implies not only equality and fairness in the award of salary but also in the granting of academic rank, a statistical method examining multiple criteria or dependent variables simultaneously with multiple predictors or independent

variables would have applicability. A multivariate alternative to multiple regression analysis which has this capability is canonical analysis. It allows a set of criterion variables to be examined in relation to a set of predictor variables, and in addition identifies individuals whose "combined" predictor score (i.e., score on a canonical predictor variable) does not correspond to their "combined" criterion score (i.e., score on the corresponding canonical criterion variable).

Canonical analysis and multiple discriminant analysis differ basically from multiple regression analysis in that they identify new, more parsimonious coordinate systems for representing the relationships among the multiple variables (Anderson, 1958; Rao, 1952, 1965). While multiple regression analysis, as customarily carried out, uses the variables themselves as the coordinates, canonical analysis and multiple discriminant analysis identify new coordinates in terms of the eigenvalues (characteristic roots or latent roots) and eigenvectors (characteristic vectors or latent vectors) of the appropriate correlation-covariance or dispersion matrices, solved in terms of certain statistical criteria. The basic statistical criterion for the eigenvalues and eigenvectors in canonical analysis is maximizing the correlation between the two sets (the predictor set and the criterion set) of variables. For multiple discriminant analysis, the criterion involves maximizing the differences between the groups in terms of the multiple measurements. These new coordinate systems not only summarize the relationships among the variables but also can provide meaningful insight into the nature of the decision-making process (e.g., how important is a specific variable in decisions on the award of rank or salary).

Canonical analysis and multiple discriminant analysis as practical procedures in the evaluation of salary equity-parity in an institution of higher education are illustrated in this paper. The illustration is based on data examined in the annual salary adjustment process at the University of Wisconsin-Superior, one of the institutions in the University Cluster of the University of Wisconsin System.

Canonical Analysis

The statistical procedures described in this paper were used for two successive years (1981-82 and 1982-83) on the University of Wisconsin-Superior campus. Data were analyzed for all full-time ranked faculty with a 100% appointment. Table 1 gives the univariate statistics for the 113 faculty members in the 1981-82 study and the 111 faculty members in the 1982-83 study. No discrete or qualitative variables were included in the canonical analysis. The data were pooled for gender, academic division

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Table 1 about here

(business, education, fine and applied arts, humanities and social sciences, and science and mathematics) and tenure status. Quantitative variables shown in Table 1 were rank and salary as criterion variables, and number of advisees, training code, and student credit hour production as predictor variables. Rank and salary together comprised the composite criterion, with full professors being given rank "1", associate professors rank "2", assistant professors rank "3", and instructors rank "4". The salary figure

Table 1

Canonical Analysis Summary of Variables

Set	Statistics[a]	1981-1982 Faculty Data (N=113)		1982-1983 Faculty Data (N=111)	
Criterion		Rank	Salary	Rank	Salary
	M	1.98	25,599	1.95	28,366
	s	0.94	6,076	1.00	6,686
	CV	47.66	23.74	51.31	23.57
	b_1*	0.536	-0.489	0.885	-0.139
	b_2*	2.282	2.293	1.442	1.686
Predictor		Number Advisees	Training Code	Student Credit Hours	Number Advisees	Training Code	Student Credit Hours
	M	10.91	1.77	218.04	13.89	1.79	200.94
	s	10.59	1.13	138.03	17.53	1.13	150.00
	CV	97.09	63.62	63.31	126.22	62.98	74.65
	b_1*	0.145	0.945	0.075	-0.044	1.001	0.009
	b_2*	-0.816	0.088	0.848	-0.514	0.082	-0.779

[a] M= arithmetic mean, s= standard deviation, CV= coefficient of variation,

b_1* = standardized coefficient, first canonical variable,

b_2* = standardized coefficient, second canonical variable

used was the academic year salary, and excluded any additional earnings due to full or partial summer employment on the campus. The composite predictor included the number of student advisees assigned to the faculty member at the beginning of the fall academic session, the faculty member's training code, and student credit hour production for all students registered in classes, including independent study and thesis, with the faculty member in the fall academic session. The training code assigns the value of "1" to the earned doctorate, "2" to two years of full-time graduate study after the master's degree, "3" to one year of full-time graduate study after the master's degree, "4" to the master's degree, and "5" to the baccalaureate degree.

The statistical theory of canonical analysis was developed by Harold Hotelling in 1936 and essentially expanded the concept of multiple correlation from that for a single criterion or dependent variable to that of multiple criteria or dependent variables (Anderson, 1958; Das, 1965; Hotelling, 1936; Rao, 1952, 1965). The advent of digital computers and the subsequent software development have made canonical analysis computationally practical. The canonical correlation analysis used in this study was Program P6M in the biomedical computer programs generated at the University of California (Dixon & Brown, 1979; Dixon et al, 1981). Table 2 gives the eigenvalues, which are the squared canonical correlations, for the 1981-82 and 1982-83 faculty data.

Table 2 about here

The first eigenvalue is the linear combination of variables that maximizes the correlation between the first (criterion) and the second (predictor) set of

Table 2

Canonical Correlations and Significance

Statistics	1981-1982 Faculty Data (N=113)	1982-1983 Faculty Data (N=111)
Eigenvalue 1	0.39844	0.41799
Eigenvalue 2	0.02135	0.13641
Canonical Correlation 1	0.63122	0.64652
Canonical Correlation 2	0.14610	0.36934
Bartlett's Test		
Chi Square 1 [a]	57.75**	73.61**
Degrees of Freedom	6	6
Chi Square 2 [b]	2.35	15.69**
Degrees of Freedom	2	2

[a] for the first eigenvalue

[b] for the second eigenvalue

** $p < 0.001$

variables. This first linear combination represents the first coordinate in the new, parsimonious coordinate system. The second eigenvalue represents the maximal correlation between the two sets of variables after removal of the correlation accounted for by the first eigenvalue. It serves as the second coordinate in the new coordinate system. The canonical correlations are the square roots of the eigenvalues, and represent the correlations between the corresponding predictor and criterion coordinates or eigenvectors.

To determine how many more eigenvalues are required to account significantly for the dependence or correlation between the two sets of variables, Program P6M computes Bartlett's test which gives a value distributed as chi square for determination of significance. For the 1981-82 data, one eigenvalue was sufficient to account for the dependence or correlation between the two sets of variables; for the 1982-83 data,two eigenvalues were required (see Table 2). Referring back to Table 1, the weighting of each of the criterion and predictor variables on the first eigenvector or canonical variable is shown by the standardized coefficients (mean equal zero, standard deviation equal unity) denoted by b_1*; the coefficients for the second canonical variable are denoted by b_2*. Since a higher salary is associated with a higher academic rank, the opposition of sign on the two criterion variables would be expected. In both the 1981-82 and 1982-83 data, training code has the highest standardized coefficient on the first canonical variable. The other two predictor variables, number of student advisees and student credit hour production, have minimal coefficients on the first canonical variable and are instead heavily weighted on the second canonical variable or eigenvector.

To utilize the results of canonical analysis for salary and rank equity-parity determinations, canonical scores are computed for each faculty member. Using the canonical variable coefficients, with the original variable measurements expressed as standard or normalized scores (mean equal zero, standard deviation equal unity), a canonical score can be computed for the criterion variables and a separate canonical score can be computed for the predictor variables. These two values can then be plotted on a bivariate graph, or otherwise compared to identify individuals whose criterion and predictor canonical scores suggest equity or inequity. Disparity in absolute values, or opposition of sign, of the two canonical scores for an individual faculty member suggests that inequity may be present. For the administrator, identification of possible cases of inequity through the canonical analysis simplifies the first stage in the evaluation of salary and rank equity-parity, as illustrated in Table 3.

Table 3 about here

Multiple Discriminant Analysis

The variables employed in comparing different groupings of the faculty, as illustrated in Tables 4 to 7, were age, number of student advisees at the beginning of the fall academic session, academic year salary, years in present rank, and years since original appointment on the campus. The grouping used for the present illustration is tenure, with tenured faculty being contrasted with nontenured faculty. Age, years in rank, and years since original

Table 3

Canonical Scores for Illustrative Cases

Data	Faculty Member	Canonical Scores		Possible Inequity?
		Criterion	Predictor	
1981-1982	019	2.0318	1.7100	no
	042	-1.0194	-0.9052	no
	010	0.0471	0.0141	no
	145	1.1717	-0.1833	yes
1982-1983	013	2.0804	1.9740	no
	001	-1.0131	-0.7242	no
	085	0.0936	0.1875	no
	015	1.1097	-0.7030	yes

appointment are all expressed in whole numbers in relation to the end of the fiscal year. Both years in rank and years since original appointment refer only to the appointment at the University of Wisconsin-Superior. Table 4 gives the univariate statistics for the variables examined in the multiple discriminant analysis.

Table 4 about here

The concept of group divergence was developed by P.C. Mahalanobis as early as 1930, with elaboration of the generalized distance measure, D^2, in 1936 (Mahalanobis, 1930, 1936). Identifying a function which would maximally discriminate between groups was initially formulated by R.A. Fisher in 1936, contrasting two groups in terms of multiple measurements or variables (Fisher, 1936, 1938). The work of Mahalanobis and Fisher was not entirely independent, as they were in communication with each other at Cambridge University. Fisher's work and Mahalanobis' initial work were further elaborated by C.R. Rao to the problem of multiple groups, permitting both a function maximally discriminating between the groups and a measure of distance between groups, in terms of dispersion matrices for the multiple variables or measures (Rao, 1946, 1952, 1965; Mahalanobis, Majumdar & Rao, 1949). Multiple discriminant analysis is computationally practical with BMDP Program P7M (Dixon & Brown, 1979; Dixon et al, 1981). Program P7M allows the investigator to set the F ratio at which variables will enter and leave the analysis, and should a state of inequity exist, it would be revealed by the

Table 4

Univariate Summary of Discriminant Analysis Variables

Variables	Statistics[a]	1981-1982 Faculty Data		1982-1983 Faculty Data	
		Tenured (N=79)	Nontenured (N=34)	Tenured (N=86)	Nontenured (N=25)
Age	M	52.78	36.21	52.91	37.96
	s	7.48	6.96	7.45	7.29
	CV	14.17	19.22	14.08	19.20
Number of	M	9.33	14.59	12.02	20.32
Advisees	s	8.90	13.18	12.48	28.32
	CV	95.42	90.33	103.79	139.37
Student	M	214.87	225.38	194.62	222.68
Credit	s	135.14	145.49	139.84	182.29
Hours	CV	63.08	64.55	71.86	81.86
Salary	M	28,615	18,593	30,346	21,554
	s	4,447	2,496	5,187	6,873
	CV	15.54	13.42	17.09	31.89
Years in	M	7.87	1.71	9.00	3.00
Rank	s	5.52	1.43	5.93	3.42
	CV	70.14	83.57	65.90	113.86
Years since	M	16.16	2.76	16.65	4.12
Original	s	4.42	2.13	4.47	3.75
Appointment	CV	27.35	77.15	26.84	90.90

[a] M=arithmetic mean, s = standard deviation, CV= coefficient of variation

analysis. The program will terminate without computing the eigenvalues and statistical tests if the preestablished level of significance is not met by the data, i.e., if a state of equity-parity exists.

Table 5 addresses the question of whether or not a significant difference exists between the faculty tenure groups in terms of the multiple measures or variables employed. For each of the sets of data, Table 5 gives the first eigenvalue which maximally discriminates between the two groups, tenured and nontenured faculty. This eigenvalue, in both sets of data, accounts for 100% of the total dispersion. It is statistically significant by both tests employed, Wilks' lambda criterion and Rao's approximate F ratio. The eigenvector associated with this eigenvalue gives the discriminant function, also termed the canonical variable. The equation expressing the coefficients of the multiple variables on the canonical variable, and a constant, shows the weighting of the several variables on this new coordinate. The canonical correlation expresses the relationship between the canonical variable and the tenure status grouping variable.

Table 5 about here

Discriminant scores can be computed which characterize the several groups and which permit a classification decision for each case included in the analysis as well as for future cases not included in the original analysis. The discriminant scores are computed using equations derived from the discriminant function. The equations characterizing the tenure status groups are given in Table 6, and include

Table 5

Multivariate Summary of Discriminant Functions

Statistics	1981-1982 Faculty Data (N=113)	1982-1983 Faculty Data (N=111)
Eigenvalue	3.45761	1.88683
Cumulative Percentage of Total Dispersion	100.00	100.00
Canonical Correlation	0.88072	0.80845
Canonical Variable Coefficients		
Age	a	0.05641
Salary	0.00013	0.00004
Years in Rank	a	-0.08156
Years since Original Appointment	0.20226	0.20066
Canonical Variable Constant	-5.79524	-6.20455
Wilks' Lambda Criterion	0.22434	0.34640
Steps	2	4
Degrees of Freedom	2,1,111	4,1,109
Approximate F Ratio	190.168	50.001
Degrees of Freedom	2, 110	4, 106

[a] An F ratio of 4.000 was required for a variable to enter the analysis and this variable did not reach that critical value.

coefficients for each of the significant variables and a constant. The percentage of faculty members correctly classified according to these equations ranged from 96.0% to 100.0% in the two salary equity-parity evaluations being considered in this paper. The discriminant scores characterizing the two groups are obtained by evaluating the canonical variables at the group means for the several variables.

Table 6 about here

If the discriminant analysis indicates that inequity exists in the data, then values of Mahalanobis' D^2 and posterior probabilities can be computed for each faculty member. Mahalanobis' D^2 represents the generalized distance between the discriminant score of the individual faculty member and the group means on the canonical varaible given in Table 6. These values are computed for each of the tenure status groups, as shown in Table 7. Posterior probabilities based on the ratio of the expected values of D^2 for the specific tenure group to the sum of the expected values of D^2 for both (or all) groups are also given in Table 7. The values of D^2, and more specifically, the posterior probabilities, identify individual faculty members who are incorrectly classified, according to the analysis. Given this information, administrators can examine the relevant data to determine whether or not a state of inequity exists for those faculty members.

Table 7 about here

The procedures involving multiple discriminant analysis in this paper illustrate a statistically elegant approach to the problem of qualitative variables in salary equity-parity determinations.

Table 6

Classification by Discriminant Analysis

Statistics	1981-1982 Faculty Data		1982-1983 Faculty Data	
	Tenured (N=79)	Nontenured (N=34)	Tenured (N=86)	Nontenured (N=25)
Classification Coefficients				
Age	a	a	1.08880	0.90498
Salary	0.00170	0.00118	0.00072	0.00057
Years in Rank	a	a	-1.05759	-0.79184
Years since Original Appointment	0.82677	0.01405	0.50837	-0.14549
Classification Constant	-31.74045	-11.66875	-39.85857	-22.55840
Percentage Correct Classification	97.5	100.0	96.5	96.0
Canonical Variables Evaluated at Group Means	1.20903	-2.80921	0.73390	-2.52463

[a] An F ratio of 4.000 was required for a variable to enter the analysis and this variable did not reach that critical value.

Table 7

Mahalanobis D^2 Values and Posterior Probabilities for Illustrative Cases

Data	Tenure Status	Faculty Member	Classified as Tenured		Classified as Nontenured		Classification Correct?
			D^2	P [a]	D^2	P [a]	
1981-1982	Tenured	117	4.7	0.863	8.4	0.137	yes
	Tenured	174	4.8	0.334	3.4	0.666	no
	Nontenured	008	17.3	0.000	0.6	1.000	yes
	Nontenured	014	8.9	0.042	2.7	0.958	yes
1982-1983	Tenured	047	3.7	1.000	19.1	0.000	yes
	Tenured	049	3.3	0.477	3.1	0.523	no
	Nontenured	041	14.2	0.019	6.3	0.981	yes
	Nontenured	074	14.0	1.000	30.5	0.000	no

[a] Posterior probability

FOOTNOTE

The computations reported in Tables 1 to 7 were carried out on the PDP 11/70 (Digital Equipment Corporation) academic computer (CPU 352 K words; RP 04 and RP 06 disks) at the University of Wisconsin-Superior, a licensed site for BMDP 1979 and 1981, using the PDP-11 version licensed by Software Development Inc., Middlebury, Vermont. Assistance provided by Mr. Eric Stamm and Ms. Amy Wright in the statistical analysis is acknowledged with pleasure.

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